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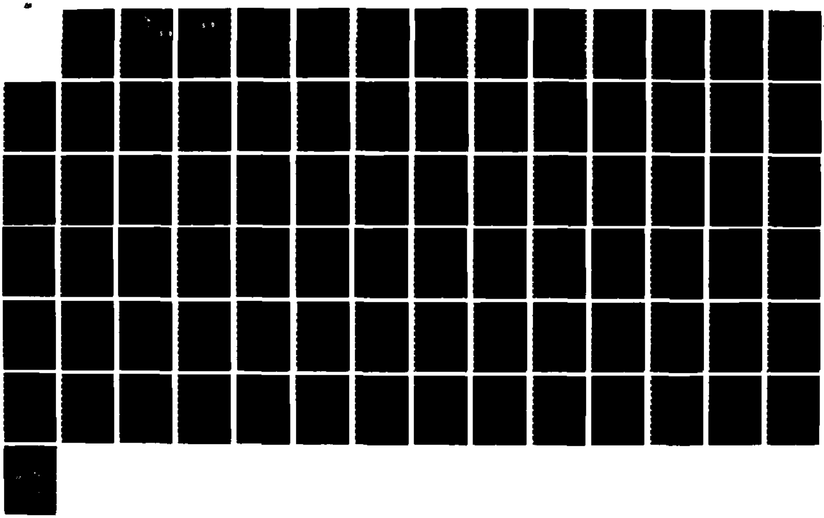

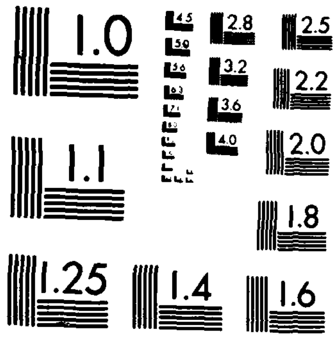

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A SLAM SIMULATION MODEL FOR CAPABILITY
ASSESSMENT OF BASE LEVEL REFUELING
DURING AIRCRAFT SURGE OPERATIONS

THESIS

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Captain, USAF

AFIT/GLM/LSM/86S-45

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AFIT/GLM/LSM/86S-45

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THESIS

Presented to the Faculty of the School of Systems and Logistics

of the Air Force Institute of Technology

Air University

In Partial Fulfillment of the

Requirements for the Degree of

Master of Science in Logistics Management

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Captain, USAF

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Approved for public release; distribution unlimited

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Abstract

This ~~research~~ develops a simulation model to of the base level refueling operation during surge conditions. Refueling data, representing surge operations, was collected and used to describe model variables. A simulation language available on the Z-100 microcomputer, SLAM II, was used to encode the model. The model simulated the refueling of aircraft under surge operations using refueling trucks, hot pits, and fillstands. The model is general enough to allow the user to vary the number of aircraft, refueling trucks, hot pits, and fillstands in order to determine how long the refueling operation will take.

The analysis was accomplished using a paired difference experiment. Two individual designs, having different combinations of refueling equipment, were tested to determine if the model could provide the decision maker with the best configuration of equipment. The results of the experiment indicated that the model could provide an output useful in choosing between alternative configurations of equipment.

A SLAM SIMULATION MODEL FOR CAPABILITY ASSESSMENT OF BASE LEVEL REFUELING DURING AIRCRAFT SURGE OPERATIONS

I. Introduction

Overview

The purpose of this research project is to develop, validate and verify a simulation model for assessing the base level refueling capability of Tactical Air Forces (TAF) during aircraft surge operations. This chapter gives a brief background of base level refueling, a statement of the problem, the research objectives, scope of the effort, and justification for this research effort.

General Issue

The base supply Fuels Branch plays a vital part in the turn-around process of aircraft during sortie generation and regeneration. As part of a highly orchestrated team effort with operations, maintenance, and support functions, the Fuels Branch attempts to optimize available resources in order to support aircraft sortie production.

In recent years, aircraft sortie production capabilities have been greatly improved by the United States Air Force's adoption of the Production Oriented Maintenance Organization (POMO) (7). POMO was used by the Israeli Air

Force in the 1973 Yom Kippar War and proved to be a highly effective method of increasing aircraft sorties in the tactical environment. POMO has led to a significant increase in aircraft sortie production capability also in the USAF. Along with maintenance and munitions operations, the ability of the base level refueling operation to meet sortie regeneration requirements has become an intergral part of POMO's success. This thesis is a discussion of the capability of base level refueling, and proposes a model to optimize the resources available to the Fuels Branch in supporting tactical aircraft surge operations.

Currently, Air Force Major Commands (MAJCOM) track two refueling capability indicators for planning purposes: Sustained Dispensing Capability, and Maximum Dispensing Capability (4:21). Both refueling capability indicators are based on subjective values assigned by base level fuels managers. What is needed is a better method to quantify base level fuels operations capability.

At present, fuels managers have no tools to aid them in determining the optimal combination of equipment and resources for the refueling operation. The Air Force uses many logistics models, and particularly the Dyna-METRIC model, for capability assessments (2; 5; 10). However, there are no specific models to assess the capability available to base level fuels managers. Measuring SDC and MDC attempts to determine only the amounts of fuel that can be issued through the system as a whole. This information

is valuable to the MAJCOM, but is of limited use to the fuels manager at the base level. Therefore, the issue at hand is to develop a simulation model which will aid the base level fuels manager in allocating and effectively using available resources to meet mission requirements.

Problem Statement

The base level refueling operation employs refueling trucks and hydrant systems as resources to refuel aircraft. Fuels management establishes procedures for refueling aircraft in order to meet the generation schedule levied upon maintenance personnel by mission requirements. Fuel is transferred from bulk storage to refueling trucks primarily from three fillstands. Hydrants are used primarily as hot pits for fighter aircraft and as cold pits for other aircraft.

While fillstands are specifically designed for and limited to filling trucks, hydrants can have a dual role as a fill point for trucks or aircraft. The decision to convert a hydrant to a fill stand normally requires the allocation of scarce manpower to act as fillstand operators.

Methods used by fuels managers to increase refueling capability are usually based on years of experience and locally developed heuristics. However, when multiple servers and different types of servers are varied, the computations for a mathematical solution can become too difficult for hand calculation. The exact quantity of hot

pits needed and hydrants to convert to fillstands to support a tactical fighter wing's surge operation is a complex optimization problem. Fuels management needs a model to aid in the decision to trade aircraft fillstands for truck fillstands, and to measure the impact in terms of effective utilization of resources.

Justification

In October 1985, Major General Skipton (USAF/LEX) stated the need for computer models to assess refueling capability in the Air Force (14). Output from a validated simulation model would allow higher headquarter staffs to accurately assess the refueling capability of units. Additionally, a model could be used as a planning tool for major exercises.

A simulation model designed for branch level execution could assist fuels managers in their duties. With a valid simulation model based on real-world data, a fuels manager could gain a better understanding of the refueling operation as a whole system. A properly documented simulation model could aid the fuels manager in planning the configuration and use of refueling equipment necessary in order to meet mission requirements. The model could identify bottlenecks, choke points, slack resources, and help investigate alternatives without consuming valuable resources. A model could also provide the fuels manager a better understanding of what effect the various combinations of equipment and facilities have on servicing times during wartime surge conditions.

Research Objectives

This research proposes a network simulation model which allows fuels managers at the base level to assess refueling capability. In order to solve the stated problem, the following research objectives were developed.

1. Create a base level refueling capability assessment model in a language and format usable at TAF base level fuels branches.

2. Collect data from a TAF wing having fighter aircraft, refueling equipment, and an operational mission.

3. Verify the mathematical logic of the model against an empirical data base.

4. Make multiple runs with the model and manipulate the variables to test the model's usefulness in determining decision alternatives.

5. Statistically analyze the results of the comparative model to validate the utility of the model for general TAF application.

Scope and Limitations

This research is concerned with developing a model for refueling operations at tactical fighter bases. The aircraft of interest are primarily: A-10's, F-4's, F-15's, F-16's, and F-111's. The model's usefulness will, therefore, be limited to operations on established tactical bases. Due to time and funding limitations, however, only statistical data from Langley AFB was collected and used to form the data base to run the object model. Langley AFB was selected because it has tactical aircraft, the type of refueling equipment to be modeled, and readily available data on aircraft surge operations.

The specific scenario to be dealt with by the model is ground refueling operations during the recovery of tactical aircraft during surge operations. The model will only be concerned with hot pit and refueling truck servicings during aircraft surge operations. The performance measure of the model is total completion time for refueling of all aircraft participating in the surge operation. Fuel consumption and resupply will not be addressed. The model will be designed such that modifications can be made as assumptions and circumstances change. This will allow managers to reconfigure the model as needed when the system or assumptions change. Changing the values of the variables in the model for different tactical fuel activities and events will be a relatively simple task and will not affect the conceptual framework of the model.

For the purpose of the model, the following assumptions were made. All assumptions are explained in chapter III.

1. All aircraft require refueling after landing. No aircraft are deferred for maintenance.

2. Sufficient numbers of equally skilled fuels and maintenance personnel are available to conduct the operations modeled.

3. The aircraft land and arrive at the aircraft servicing area at a rate of one per minute.

4. Aircraft will be routed to hot pit or refueling truck servicing based on the service activity with the shortest queue.

5. Hot pits are preferred when queues for the service activities are equal.

6. Refueling trucks service only one aircraft and then must refill.

7. The refueling truck travel time distributions between aircraft servicing area and fill-stands are the same as between the aircraft servicing area and hydrants converted to fillstands.

II. Literature Review

Overview

This chapter first describes ..ne base level refueling operation and the current methods of capability assessment employed by fuels management. Next, simulation modeling and systems theory are outlined as methods to model the base level refueling operation within stated constraints.

Base Level Refueling Operations

A description of key players in the base level refueling operation is provided to enhance the understanding of the system being modeled. The base level refueling operation is comprised of the Fuels Management and Fuels Operations sections.

Fuels Management. Fuels Management has five major sections: Fuels Operations, Quality Control and Inspection, Accounting and Administration, Training and Mobility, and Cryogenics (when authorized) (4:16). For the purpose of this thesis, only Fuels Management and Fuels Operations will be discussed. Fuels management consists of the Fuels Management Officer (FMO), who is the accountable officer for the base fuels account (4:7), and the Fuels Superintendent, a noncommissioned officer in the grades E-6 to E-9. The FMO and the Fuels Superintendent together make up the fuels management team jointly responsible for the operation of the fuels branch. AFR 144-1 identifies 22 separate responsibilities

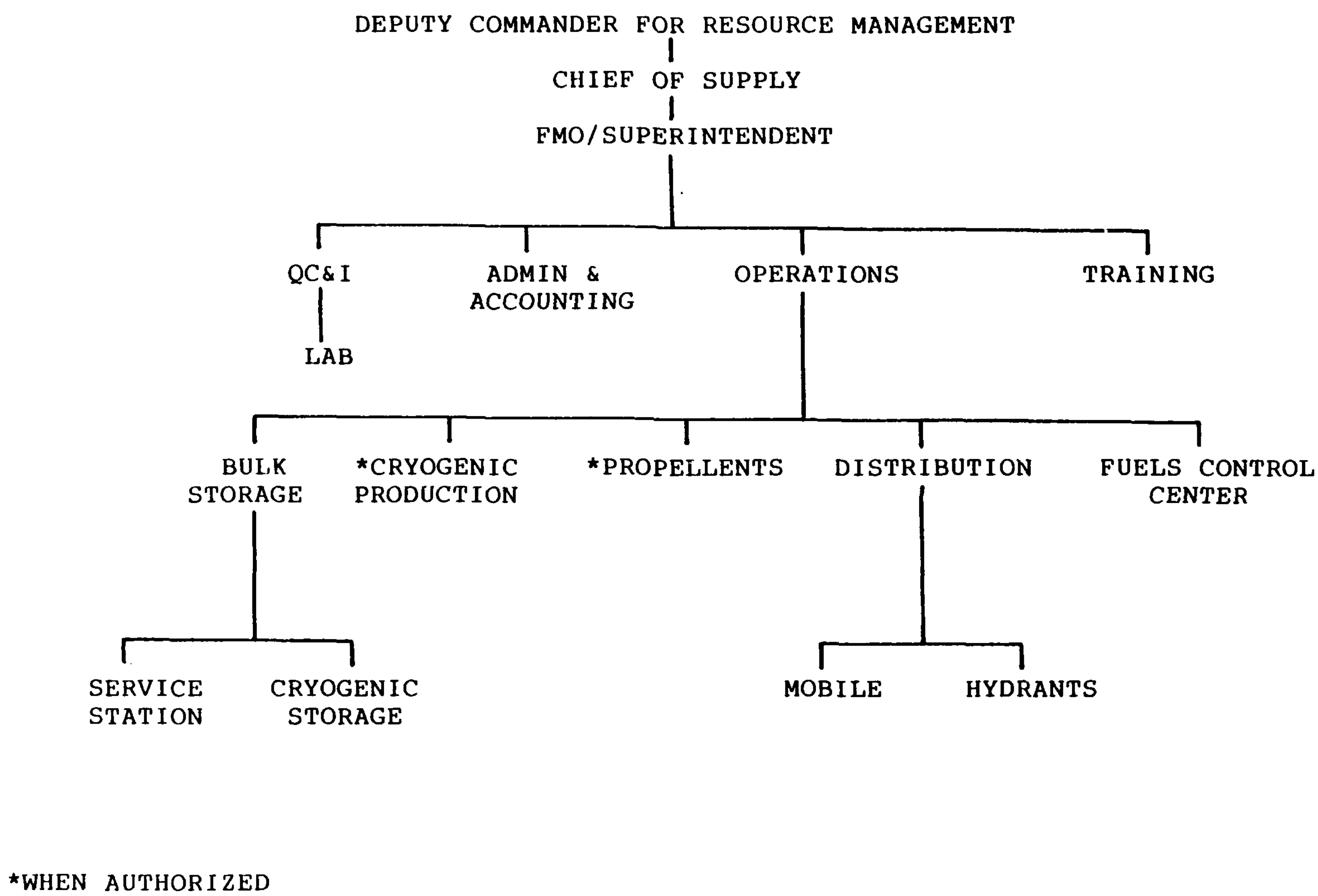


Figure 1. Fuels Organization

for fuels management. Primarily, fuels management is responsible for managing the requisition, receipt, storage, issue, and accounting of all petroleum fuels, demineralized water, and missile propellants. Fuels management also supervises fuel servicing operations and personnel, and develops and implements emergency fuel support plans with the aide of the Fuels Operations Section (4:7).

Fuels Operations Section. The Fuels Operations Section consists of the Fuels Control Center (FCC), Storage, Distribution, and Propellants (when authorized) (4:16). The Fuels Operations Section of Base Supply is responsible for the receipt, storage, transfer and issue of all fuels products and associated refueling equipment and facilities (4:48). In order to accomplish this, the Fuels Operation Section relies heavily upon the FCC, which acts as the command and control point for all operations.

Fuels Control Center. The FCC is the heart of the command and control system for fuels operations and fuels management. The FCC controller is responsible for coordinating, scheduling, and controlling all fuels operations for fuels management (4:48). During normal operations, all refueling requests are taken by the FCC controller, and crews are dispatched as required. Additionally, refueling data is collected and recorded by the FCC to ensure standards and guidelines for response times set in AFR 144-1 are being met.

Frequently, assistance is required to monitor aircraft servicings during daily or routine operations and aircraft surge operations. The operations expediter, using a radio and vehicle, closely monitors the progress of refueling operations and assists the FCC (4:48). When necessary, the expediter coordinates refueling requests directly with the maintenance flight line supervisors. This eliminates the time delay normally incurred when refueling requests are routed through the Maintenance Operations Center to the FCC. The expediter has control of the refueling trucks and equipment on the flightline. When a refueling truck is required, the expediter radios FCC and a driver is dispatched from the Distribution section.

Distribution and Storage Sections. Distribution section personnel operate mobile refueling trucks and man hydrant systems on the flightline to refuel aircraft. Storage section personnel receive fuel from off base, transfer fuel within bulk storage and to hydrant storage tanks, and operate hydrant pump stations. Due to an extensive training requirement, all personnel are generally qualified on flightline servicings as soon as possible after being assigned to the fuels branch. This allows relatively new personnel assigned to the storage section or the distribution sections to be used on the flightline for refueling aircraft during surge operations.

Surge operations are one of the main conditions that generate extraordinary demands on the base level refueling

system. Surge operation are also one of the most important fuels taskings, in that surge operations directly reflect the fuels branch's ability to meet wartime scenarios. During surge operations, aircraft are refueled on the ground using the fastest means available. This is generally done by one or more of the following methods: Integrated Combat Turn (ICT), hot pit refueling, hydrant or hose cart refueling, and truck refueling. Once the aircraft lands, maintenance personnel will determine the degree of maintenance required to turn the aircraft for another sortie. Unless extensive maintenance is required, the aircraft will be refueled for another sortie as part of regeneration. Maintenance personnel decide which refueling method will be used.

Capability Assessment. In order to effectively support mission requirements, thorough planning must be carried out by fuels management with the aide of the fuels operations section. This planning results in two measurements which are then used to determine refueling capability: maximum dispensing capability and sustained dispensing capability (4:21).

Maximum dispensing capability is the total amount of fuel which can be issued in a 24-hour period to aircraft, using on-hand refueling equipment and facilities. Pumps often do not operate as expected. The manufacturer's rated flow rates are sometimes higher or lower than actual flow rates because of total fuel system differences at the bases or different operating conditions from those under which the

pump was tested. Actual flow rates are therefore used in lieu of manufacturer's rated flow for calculating maximum dispensing capability (8). For surge operation lasting over 24 hours, sustained dispensing capability is calculated by using actual flow rates to determine if the surge requirements can be met (4:21).

Sustained dispensing capability is the maximum dispensing capability that can be sustained for an indefinite period. The individual flow rate for each fuels operation is calculated from receipt to issue. As stated in AFR 144-1, "The sustained dispensing capability is the lowest flow rate identified within the total bulk fuel handling complex" (4:21). Often, choke points occur in the total system. For example, the hydrants and fillstands may be able to issue 1000 barrels of fuel a day. But, if only 500 barrels can be received each day at the base, the flow rate of receipts is clearly a choke point in the total fuel system.

Computations for both maximum dispensing capability and sustained dispensing capability depend greatly on the types of equipment and facilities at the base, and the relative distance between the flightline and refueling facilities (8). The usefulness of computed results depends on the ability of fuels managers to use facilities, personnel, and equipment in the optimum configuration. The more complex the system, the more difficult it is to find the optimum configuration of facilities and equipment that maximizes dispensing capability.

Just calculating the maximum capability of a system does not guarantee that on-hand equipment and facilities can or will be properly used to achieve the maximum capabilities. The model proposed in this thesis will be designed to test alterative configurations of facilities, personnel, and equipment without employing the real world system. Before this can be accomplished, the real-world system must be converted into a simulation model.

Simulation Modeling

Simulation is the imitation of the operation of a real-world system over time (1:2). Because some management problems are often too complex to solve by hand, computer models involving algebraic methods, probability theory, linear programming, or other mathematical means can be used to imitate the behavior of the system (1:3). Simulation modeling is used to evaluate a variety of real-world systems (1:5). Simulation has many business and government applications, including: circuit design, airport operations, inventory control, job shop scheduling, and military operations (1:5).

However, in order to model a real-world system, variables and relationships within the system must be identified. According to Banks and Carson, the modeler must determine "the mathematical, logical, and symbolic relationships between entities, or objects of interest, of the system" (1:6). Simulation attempts to capture the essence

of a system by including only the variables relevant to the objective of the model. The systems approach is useful in accurately identifying mathematical, and statistical relationships.

The Systems Approach. The systems approach is considered an intergral part of simulation modeling (1:6, 13:2). In fact, Shannon defines system simulation as, the process of designing a model of a real system and conducting experiments with this model for the purpose either of understanding the behavior of the system or of evaluating various strategies for the operation of the system (13:2). A system is defined as "a group of objects that are joined together in some regular interaction or interdependence toward the accomplishment of some purpose" (1:6). Systems are often affected by variables external to their processes as well (1:6; 9:61). These variables external to the defined boundary of the system comprise the system's environment (1:6; 9:61). In order to model a system, it's boundaries and environment must be determined based on the problem the model is to solve (9:61). Systems are generally made up of smaller subsystems, each having its own environment and boundary. The boundaries and environment of each subsystem must also be determined in order to develop necessary assumptions for the model.

To model the subsystems, certain limitations must be recognized with respect to the real-world system, and

accepted as assumptions for the modeling process (1:378; 12:293). In addition to developing the assumption and limitations, the conceptual framework needed to describe the system must be determined.

World Views. Simulation modeling employs world views which are the conceptual framework or perspective from "which the system functional relationships are perceived and described" (9:60). Simulation models of systems may be either discrete change, continuous change, or a combination of both (9:64). A discrete simulation is characterized by changes in the state of the system only when an event occurs (9:65). Whereas in continuous simulation, the state of the system is continuously changing (9:65). In combined simulation, the state of the system may change continuously for periods of time while events occur at specific points in time. The orientation of the system's model is dependent on the problem being answered and need not agree with the actual system (1:10; 9:64). For example, a discrete system such as the population of fish in a lake may be modeled using a continuous model.

Three alternative world views used by modelers to describe systems are: event orientation, activity scanning orientation, and process orientation (6:65-68; 9:60; 65-68). Event orientation defines changes in the system state that occur at discrete, event times (9:66). Activity scanning orientation involves describing "activities in which entities engage and the conditions which cause an activity

to start or end" (9:67-68). The features of both event orientation and activity scanning orientation are combined in process orientation. With process orientation, certain activities such as queues are represented with a single statement. The simulation language translates the statement into the necessary sequence of events as the entities flow through the system. Process orientation's advantage is that it's relatively easy to learn but it is limited by the simulation language's standardized statements. Event orientation on the other hand, is usually more difficult to learn but is highly flexible once mastered (9:73). SLAM II provides a unified modeling framework which incorporates event orientation, process orientation, or both (9:73).

Language Selection. SLAM II, simulation language for alternative modeling, is used to model the base level refueling operation. Slam II was chosen as the modeling language for the following reasons:

1. SLAM II is an efficient and highly capable language designed for simulation modeling.

2. Translating the model's subsystems into SLAM II code was relatively easy due to SLAM II's process orientation and the base level refueling operation's characteristics.

3. SLAM II provides a comprehensive output in an easy to read format.

4. SLAM II was readily available to the author.

5. SLAM II has been developed for the Z-100 microcomputer, which is available at a large number of TAF bases.

SLAM II's process orientation employs a network structure. The network structure uses specialized symbols called nodes and branches to represent key elements in a process such as queues, servers, and decision points (9:73). The modeler combines the symbols into a network model to represent the system or interest (9:73). Using the network or pictorial representation of the process, the modeler then writes the code with statements corresponding to the nodes and branches of the network model.

Network simulation models use entities, activities, and processes to model people, equipment and resources of actual systems. The network simulation model of the base level refueling operation models the aircraft and refueling trucks as entities which flow through processes. The base level refueling operation can be broken down into several distinct subsystems: aircraft refueling on hydrants, aircraft refueling by truck, truck refueling on fillstands, truck refueling on hydrants. Aircraft and refueling truck entities flow along branches (activities) through queue nodes with their respective servers (processes). Once the variables of the system have been identified, the base level refueling operation can be modeled using the network structure of SLAM II's process orientation.

Summary

The purpose of this literature review was threefold. First, the base level refueling operation was described and

the key elements involved in the refueling of surge aircraft were identified. Next, simulation modeling and the system's approach were discribed. Systems simulation as defined by Shannon was present as the *methodology* used to develop the model. Finnally, SLAM II's process orientation was discussed and reasons were given for selecting SLAM II as the simulation language for the modeling effort. These elements were essential in answering research objective #1.

III. Model Design and Testing

Overview

The purpose of this chapter is to describe the process used to create, verify and validate a simulation model of the base level refueling process. The methodology used will answer the five research objectives stated in chapter I.

The Model Building Process

In order to build a simulation model, it was essential to have a good understanding of the steps necessary for building a sound and useful model. An adaptation of a commonly used model building process, described by Banks and Carson, was used for this research (1:11). The process had eleven steps which helped guide the construction of the model. These steps were (1:11-14):

1. Problem definition and formulation.
2. Setting objectives.
3. Model building.
4. Data collection.
5. Computerizing the model.
6. Verification.
7. Validation.
8. Experimental design.
9. Production runs and analysis.
10. Document program and report results.

11. Implementation.

Each step will be discussed as it applied to this model.

Problem Definition and Formulation

The first step of the model building process was to conceptualize or define the problem (1:11; 9:10; 13:290). The section in Chapter I, titled 'Problem Statement', defines the problem under study for this thesis.

Setting the Objective

This research concentrated on how the alternative use of hydrants as fillstands for refueling trucks affected base level refueling operations under surge conditions. The model needed to provide fuels managers with a method of determining the optimum solution to provide adequate refueling capability, without actually using the real world system on a trial and error basis. The specific objective of the model was: What combination of available refueling trucks, fillstands, and hydrants would provide fuels management with the most effective method of refueling under surge operations. Once the problem was formulated and the objective set, the next step was building the model.

Model Building

According to Banks and Carson, "The construction of a model of a system is probably as much art as science" (1:13). Model building is a reiterative process of trial and error, best learned by building the model from a simple

form and proceeding to the final, more complex form. The modeler must identify the important features of a problem, extract the essence of the relationships within the system relative to the problem, and then build and rebuild the model until useful results are obtained (1:13). Not every aspect of the system is modeled, only the essence of the actual system needed to answer the problem.

Using the simulation modeling methods described in Chapter II, the base level refueling operation was analyzed as a system and reduced into subsystems. Only operations involving F-15 aircraft were modeled. The system analysis was limited to the F-15's and associated support equipment. Other aircraft assigned to Langley AFB were not included in the model.

Two subsystems, each representing a process through which entities flowed, were designed. The first subsystem was defined as the hot pit servicing of aircraft. This subsystem was modeled as a simple queue with multiple servers. Aircraft, entites in the system, landed and taxied to the aircraft servicing area. There, the aircraft lined up for hot pit servicing. After servicing, the aircraft taxied to the aircraft parking area, and were then available for maintenance. This completed the activities in the first subsystem.

In the actual system, if fuel cell maintenance or other major maintenance was required on the aircraft when it landed, the aircraft went directly to a designated parking

area for maintenance without fuel servicing. For the purpose of this research, the model did not reflect aircraft component or refueling equipment failures. The data base considered only those aircraft which landed and were ready for immediate refueling.

The second subsystem involved aircraft refueled by truck and the related process through which refueling trucks were themselves refilled. In the actual system, refueling trucks are maintained with a full load of fuel. The model reflected this by starting up with the refueling trucks waiting for aircraft to arrive. The refueling trucks were dispatched to the aircraft parking area and waited for the maintenance crew chief to signal that the aircraft was ready to take on fuel. The waiting time is part of the data base time frame for an aircraft servicing by refueling truck. Therefore the normal distribution used in the model includes this time. The refueling truck operator and the maintenance crew chief jointly refueled the aircraft. This research assumes refueling trucks service one aircraft per fuel load. Once the refueling truck completed the refuel, it then refilled at the fillstands and returned to the aircraft parking area for more servicings.

In order to refill, the refueling truck traveled to the fillstands after each aircraft servicing. The model used one travel time and one queue for all the refuel trucks waiting for fillstand servicing. This reflected the operation of an actual system with three fillstands in one

location. When a fourth or fifth fillstand was added, it was a hydrant located on the aircraft parking ramp. The travel times for hydrants will likely be different from what was modeled. In the actual system, the operations expediter is responsible for directing the refueling truck to the next available fillstand, and should consider the time difference. For the purpose of this model, the assumption was made that the distribution for travel times would be the same for both fillstands and hydrants being used as fillstands. When the refill operation was completed, the refuel truck left the fillstand and returned to the refueling truck parking area to await the next request.

Data Collection and Analysis

In order to assign realistic values to all variables, and to identify their correct relationships, data collection and analysis was performed. Data was collected from refueling records maintained by the Fuels Branch at Langley AFB, Virginia. The author traveled to Langley AFB to collect data, and analyze the base level refueling operation. Through on-site inspections of the refueling facilities and through personal interviews with fuels managers, information on the base level refueling operation and refueling data were obtained. The information and data collected was used to determine which aspects of the base level refueling operation would be modeled.

Actual refueling data from a hurricane evacuation and an exercise was obtained. The Daily Fuels Request and Servicing Logs (AF Form 824) and Flightline Daily Fuels Servicing Logs (AF Form 839) represented an accurate and viable source of data with some qualifications. Figures 2 and 3 in Appendix B are examples of the AF Forms 824 and 839 used for data collection.

The specific logs chosen represented refueling operations during recovery of aircraft during surge conditions. On 25 October 1985, the Fuels Branch serviced virtually all of the wing's aircraft which were returning to Langley AFB after a hurricane evacuation. All servicing was accomplished by refueling trucks. During 5-7 November 1985, the wing participated in a self-initiated Operational Readiness Inspection (ORI). Fuel servicings were accomplished by hot pits and refueling trucks under surge conditions. Since the servicing procedures for both periods were basically the same as would be used to recover aircraft in a war environment, the data collected was suitable for the purpose of the model.

Due to the nature of the operation, exact and precise times were not always recorded by the fuels servicing operator and flightline expediter. Variations of one to three minutes from the actual time may exist in the arrival or departure times for individual servicings. Precise times for all events could be obtained by a dedicated observer with a stop watch. However, the fuels servicing operators

are involved in a hazardous, complicated task requiring their full attention, and therefore normally uses a wrist watch and close approximations when recording times during surge operations. As a result, some figures may represent an average time or a close approximation to the actual time for servicing.

For example, during the November 1985 exercise, one hot pit operator recorded 4 straight servicings each taking 13 minutes per aircraft. But the aircraft had significantly different fuel loads. In reality, the fuel loads would have caused the servicing times to vary. However, the fuel servicing operator may have missed recording the individual servicing times for a short period and recorded the average time for each aircraft for the period (Note: for planning purposes, MAJCOM's frequently use a constant figure, for example fifteen minutes per hot pit servicing for F-15 aircraft (8)). For the purpose of the model, all data was assumed to be accurate enough to obtain useful results.

Model Variables. Values were extracted from the AF Forms 839 and 824 to determine the distributions of the independent variables in the model. A histogram of each data set was analyzed, and an appropriate distribution was hypothesized. Next, estimated parameters for the hypothesized distributions were obtained using the AID Computerized Theoretical Analysis Package available on the AFIT Classroom Support Computer (CSC), a Sperry PDP 11/760. AID, developed by Pritsker and Associates, Inc., analyzes data

and preforms hypothesis testing using either the Kolmogorov-Smirnov one sample test (K-S test), or the Chi-Square test. Since sufficient data was available, the Chi-Square test was used to perform hypothesis testing against theorized distributions chosen by the author.

From an analysis of the subsystems, four independent variables related to the model's performance were identified: hot pit servicing time, refueling truck servicing time, refueling truck travel time, and fillstand servicing time. These variables were instrumental in determining the output of the model. The values associated with these variables were modeled against distributions which attempted to mimic the actual system. Since aircraft other than F-15's were serviced, care was taken to use log entries for F-15 aircraft only.

Hot pit Servicing time, the first independent variable, represents the time required to service the aircraft on the hot pit. In the actual system, the fuel load of the aircraft, the actual flow rate of the fuel, and the experience level of the refueling crew all helped determine the servicing time. For the model, all these values were combined into one independent variable. A range of values for hot pit servicing time was found by extracting the servicing time from the AF Form 839. The time in the "ARR ACFT" (arrived aircraft) column was subtracted from the "DEP ACFT" (departed aircraft) time. The subsequent time required for hot pit servicing of the aircraft was then estimated to come

from a poisson distribution. Servicing times usually vary between individual servers, however,this research assumed servers' skills were identical for all refueling tasks therefore service times for all servers were equal.

The second independent variable was refueling truck servicing time. The value of the variable was dependent on the fuel load of the aircraft, the actual flow rate of the refueling truck pumping unit, and the skill level of the refueling truck operator. These values were combined into a single independent variable. A range of values for the variable was found by extracting the servicing time from the AF Form 839. The time in the "ARR ACFT" (arrived aircraft) column was subtracted from the "DEP ACFT" (departed aircraft) time. The variable was modeled as a Weibull distribution.

The third independent variable was the refueling truck travel time. It represented the time required to travel between the aircraft servicing area and the fillstand. The values of the variable were obtained by subtracting "DISPATCHED" time from "ARR ACFT" time for work orders sending refueling trucks to the fillstand. Since there is no entry on the log sheet corresponding to the return trip to the aircraft servicing area, the distribution for going to the fillstand was also used for returning to the aircraft servicing area. Refueling trucks returned to the fuels yard, parking area before being dispatched again, unless an aircraft was waiting. Under the surge conditions of the

model, trucks always returned to the aircraft servicing area. The travel time variable was modeled being from a poisson distribution.

The forth independent variable of the model was fill-stand servicing time. This represented the time required to fill the refueling trucks at the fillstand plus the time required to finish paperwork before leaving the fillstand yard. The values of the variable were obtained by subtracting the "START FUEL" time from the "DEPT ACFT" time for work orders sending refueling trucks to the fillstand. The fillstand servicing time variable was modeled using a normal distribution.

Selected output from the AID program is presented in Appendix B for each of the data sets. These include the actual data, the distribution selected, the parameters of the distributions, and the Chi Square analysis performed by AID.

Additionally, four dependent variables were identified: number of aircraft to service, number of hot pits, number of fillstands, and number of refueling trucks available. These variables were used to design a particular system configuration for the model to simulate. A description of each variables role in the model is provided.

The first dependent variable, number of aircraft, was set to simulate 72 aircraft landing at the base. Since the model simulates surge conditions, the arrival rate is set at one aircraft per minute. This ensures aircraft will be

arriving at the servicing activities without breaks between arrivals of more than one minute. At the model startup, queues will not form until all servicing activities become busy. The model terminates after 72 aircraft have been serviced.

The second dependent variable, number of hot pits, was set at four in the model. The refueling data indicated that Langley AFB used four hot pits during surge operations. Langley AFB also has additional pits which can be used as additional hot pits or as fillstands for refueling trucks.

The third dependent variable was number of fillstands. Langley AFB has three fillstands for servicing refueling trucks. This number may be increased by opening a pit as a fillstand or reduced to simulate the loss of one or more fillstands.

The fourth dependent variable was the number of refueling trucks available. Langley AFB has 18 R-9 refueling trucks. Two of the refueling trucks were used as defuel trucks. The refueling trucks were themselves subject to maintenance failures. Since data was not available for determining a failure distribution, no attempt was made to include refueling truck failures. Other assigned aircraft also required servicing at Langley AFB. For the purpose of this model, 12 of the available 16 refueling trucks were assumed to be refueling only the F-15 aircraft.

Computerizing the Model

The final phase of model formulation was marrying the subsystems into the overall system and then computerizing the model. The model was written in SLAM II simulation language, compiled, and run on the CSC computer system at AFIT. Appendix C contains the model's code and an explanation of each line's function.

Verification/Validation

Verification and validation were conducted simultaneously with model building as a reiterative process rather than a linear process (1:379). According to Banks and Carson, the goal of the entire process was,

> 1. to produce a model that represents true system behavior closely enough for the model to be used as a substitute for the actual system for the purpose of experimenting with the system;
>
> 2. to increase to an acceptable level the credibility of the model so that it will be used by managers. (1:377)

Verification. Three classes of verification techniques were used to verify the model. The first class involved what Banks and Carson called common sense methods. The methods are:

1. Have another programmer check the code.
2. Use flow diagrams to help illustrate logic of code.
3. Examine model outputs and compare to expected values or a range of values.
4. Check input parameters at the end of program run for value changes.

5. Include documentation in the code explaining the variables, code functions, and subroutines. (1:379)

Method #1 was used in the early stages of coding the model. AFIT instructor, Major J. Litko examined the code and gave helpful suggestions in the early stages of encoding the model. Using method #2, flow diagrams were used to map out the system's logic and the flow of entities through the processes. Additionally, SLAM II's specialized symbology was used in developing the code. As the model evolved, method #3 was used when the model's output was checked at each iteration. Changes were made when obvious errors were discovered. For example, 72 aircraft were being created but the simulation would terminate before all aircraft were serviced. The problem was with the selection rule used to chose between hot pit servicing and refueling truck servicing. Entities were being blocked and destroyed in the process. A correction was made to create numerous aircraft entities and allow the simulation to terminate even though entities were still in the system. Method #4 was used during a trace run which will be discussed later in the section.

Method #5, documenting the code, was especially helpful in the early stages of encoding the model. SLAM II's code is self-documenting to a large degree. The SLAM II models run on the CSC computer contained remarks identifying key variables and points of interest.

The last verification technique used the trace function. The trace function caused every event to print out with associated values as they happened in the simulation. The trace function was used to verify the function of the segment of code which assembled the aircraft and refueling trucks for servicing, and then separated them. The trace function caused over 500 lines of events to print out and was therefore not included as a part of this thesis. In conjunction with verification, validation and calibration was also being performed on the model.

Validation. According to Banks and Carson, "Validation is the overall process of comparing the model and its behavior to the real system and its behavior" (1:383). Additionally, calibration is

> the iterative process of comparing the model to the real system, making adjustments, (or even major changes) to the model, comparing the revised model to reality, making additional adjustments, comparing again, and so on. (1:383)

Calibration was preformed again and again until the subsystems and eventually the final model produced an accurate reflection of the base level refueling operation. Perfect reflective behavior was not possible nor was it the goal of the validation effort. The objective was to obtain an accurate model within the constraints of time and modeling effort.

In order to obtain an accurate model, the subsystems were first validated using a three-step approach involving:

1. Face validity,

2. Validation of model assumptions, and

3. Model input-output transformation comparison to real system input-output transformation. (1:385)

The first step involved building face validity in the model. Having a thorough understanding of the base level refueling operation was essential in giving the model face validity. Building into the model a high degree of realism was possible because of the author's experience with the system. Additionally, Capt B. Silver, an experienced fuels officer assigned to AFIT, made contributions to the model's realism. Once the model's face validity was constructed, the model assumptions were validated.

The second step, validation of model assumptions, was conducted in two ways. First, AID was used to validate the data distributions using Chi-Square testing. Also, the generated random variables were given a cursory examination for value and range, and compared to the actual data. The validity of SLAM II's internal random number generators were not statistically tested. Instead, the check was to insure the distributions were encoded correctly. Next, the structural assumptions were checked against known system behavior. Close attention was paid to the results of queue selection rules. SLAM II's simulation language handles most of the structural processes with one statement, thus reducing the effort needed for structural validation.

The third step involved model input-output transformation comparison to real system input-output transformation.

This was preformed by first running the hot pit servicing subsystem model and comparing it against the real system's operation on 5 November 1985. Ten runs of the final subsystem model gave the results listed in the following table.

TABLE I

Hot Pit Servicing Completion Times

RUN NUMBER	COMPLETION TIME
1	565
2	557
3	562
4	569
5	564
6	563
7	565
8	561
9	547
10	554

Mean completion time for the simulation of 168 aircraft servicings by 4 hot pits was 560.7 minutes with a sample standard deviation of 6.41 minutes. The actual system's completion time for 5 November 1985 was 578 minutes. The model's mean value was reasonably close to the actual system's value, because the actual value was within 3 standard deviations of the model value. The next step was to compare the model run against the results of the other two days of hot pit refueling data.

Both subsystems were considered valid for the purpose of this research. However, empirical data was not available for comparison of input-output transformations for the refueling truck servicing subsystem, or the combined subsystems in the

final model. Due to time and funding constraints, a final check was not completed on the model, which is considered a limitation of the final model's validity.

Experimental Design

According to Pritsker, "a simulation run is an experiment in which an assessment of the performance of a system is estimated for a prescribed set of conditions" (9:520). The objective of this simulation experiment was to demonstrate the model's usefulness in making a choice between a set of alternatives. The alternatives being different combinations of the input design factors such as number of hot pits, refueling trucks, fillstands, and hydrants converted to fillstands. The statistic of interest is the completion time for refueling 72 aircraft. Since the model will terminate when 72 aircraft entities have been serviced, the current time at the end of the simulation run is used. The experimental design consisted of running the model with two possible combinations of aircraft (A/C), hot pits (HPT), refueling trucks (TRK), and fillstands (FSD) as shown in Table II.

Design X employs 4 hot pits, 12 refueling trucks, and 3 fillstands to service 72 aircraft. Design Y employs 4 hot pits, 12 refueling trucks, and 4 fillstands to service the same 72 aircraft. Since Langley only has 3 fillstands, the fourth fillstand was actually a hydrant outlet converted to a refueling truck fillstand. The model results should show

that with Design Y, the aircraft can be refueled in less time than with Design X, because there are more refueling resources available.

TABLE II

Input Design Factors

DESIGN	#A/C	#HPT	#TRK	#FSD
X	72	4	12	3
Y	72	4	12	4

These specific factor values were chosen for several reasons. First, current sortie production rates as shown in the empirical data suggest that 72 aircraft regenerations for one span of time is not unreasonable. Secondly, the use of 4 hot pits matches the number used in the data base for Langley AFB. As for number of refueling trucks, Langley has approximately 18 refueling trucks assigned. Two refueling trucks are used for defuel trucks, one to two are commonly out of commission for maintenance (based on experience), and several refueling trucks may be required to support other base requirements. As a result, the factors are considered reasonable and compatible to the data base of the model. By comparing the completion time for refueling all aircraft between the two designs, X and Y, the experiment should give statistical evidence of significant difference between the two sample means ($\overline{X} - \overline{Y}$) of model design's X and Y. The next step was to determine the number of model runs to

complete in order to ensure accuracy in a statistical test for difference in the mean of designs X and Y.

Production Runs and Analysis

The goal of this simulation experiment was to compare two model designs, and obtain point estimates of the differences in the sample means to determine if the two designs gave different results. A paired difference experiment was designed by using identical random number streams in simulation model runs for both designs. This technique was used to reduce the variance of the estimated difference of the sample means (11:358). A confidence interval was computed with the correlated data to conduct the test hypothesis:

$$Ho: \quad (\overline{X} - \overline{Y}) = 0$$

$$Ha: \quad (\overline{X} - \overline{Y}) = 0$$

The test statistic was:

$$t = \frac{\overline{X} - 0}{(S / N)^{1/2}} \tag{1}$$

where

$\overline{X}$ = the sample mean of the differences

S = the sample standard deviation of the differences

N = the number of sample means

The rejection region was $t < -t_{\alpha/2}$ or $t > t_{\alpha/2}$

A 90 percent confidence interval for the sample mean of the difference was determined using:

$$(\overline{X} - \overline{Y}) \pm t * \frac{\overline{X} - 0}{(S / N)^{1/2}} \qquad (2)$$

The total number of replications (R) required to obtain a 90 percent confidence interval with an accuracy level of 2 minutes was found by initially running the model 3 times to obtain an estimate of the variance and standard deviations. The sample standard deviation was then used to calculate the number of replications required, using the following formula:

$$R \pm ((Z \text{ X } So)/E)^2 \qquad (3)$$

where:

R = number of replications

So = sample standard deviation

E = desired accuracy criterion (2 minutes)

Z = the critical value for a two tailed 90% confidence interval (if R is large enough to use the CLT, the normal table and associated Z value may be used in lieu of the t statistic).

The initial estimate of the population variance, So^2 was calculated using the results of the initial replications found in Table III. The simulation pretest runs had a sample mean of 149.0 and a sample standard deviation of 6.245.

TABLE III

Results of Simulation Pretest Runs

RUN NUMBER	DESIGN X
1	142.0
2	151.0
3	154.0

Substituting these values into Eq (3), yielded:

$$R = ((1.645)*(6.245)/2)^2$$

$$R = 26.442$$

$$R = 27$$

Based on the preceding computations with the results of the pretest, 27 runs were made with both models.

A sample size of 27 replications allowed the use of the Central Limit Theorem (CLT) which states,

> If a random sample of n observations is selected from a population (any population), then, when n is sufficiently large, the sampling distribution of $\bar{x}$ will be approximately a normal distribution. The larger the sample size, the better will be the normal approximation to the sampling distribution of $\bar{x}$. (11:254)

To use the CLT, the sample size should be at least n=15 with no significant skewdness in the relative frequency histogram for the sample means, $\bar{x}$, or at least n=27 regardless of the population's true distribution (15:260-261). Statistical analysis using the t statistic was preformed on the results of the 27 simulation model runs for each design. Analysis of all results will be presented in Chapter IV.

IV. Results and Analysis

Overview

This chapter presents results of the model runs for each design, X and Y, and an analysis of the results. It is organized around research objectives to clarify the meaning of the results.

Research Objective #1.

Create a base level refueling capability assessment model in a language and format usable at TAF base level fuels branches.

Results. A SLAM II model of the base level refueling operation was constructed to simulate refueling operations under surge conditions. The model code is listed in Appendix C with an explanation of its operation.

Research Objective #2.

Collect data from a TAF wing having fighter aircraft, refueling equipment, and an operational mission.

Results. Data was collected from Langley AFB, Virginia, a tactical fighter base. The data represented refueling operations during wartime surge operations. The data was used to estimate the values of variables in the model. Due the wide variety of aircraft assigned to Langley AFB, the data collected on refueling truck servicing was useful only for developing the distributions for: refueling truck

servicing time, refueling truck travel time, and fillstand servicing time. An input-output transformation check was not possible on the refueling truck subsystem model and the final model.

Research Objective #3.

Verify the mathematical logic of the model against an empirical data base.

Results. Using the hot pit servicing and truck refueling data, the logic of the model and subsystems verified as operating correctly. SLAM II's simulation language compiler was instrumental in eliminating syntax and internal logic errors. The author's experience with the base level refueling operation contributed to the verification process. However, the validation of the model was limited in that the refueling truck subsystem was not validated using the input-output transformation check.

Research Objective #4.

Make multiple runs with the model and manipulate the variables to test the model's usefulness in determining decision alternatives.

Results. Two scenarios with different resources were run 27 times each to obtain sample distributions of mean completion times. Design X had three fillstands for refueling trucks where design Y used four fillstands by simulating conversion of a hydrant to a fillstand. In order to reduce the variance between the two models, common random

number generators were used. The results of the simulation runs are listed in Table IV.

Research Objective #5.

Statistically analyze the results of the comparative model to validate the utility of the model for general TAF application.

TABLE IV

Results of Simulation Runs

RUN NUMBER	DESIGN X	DESIGN Y	$(\bar{X} - \bar{Y})$
1	152.0	145.0	7.0
2	155.1	142.1	12.0
3	150.8	141.1	9.7
4	157.0	147.1	9.9
5	151.1	133.0	18.1
6	155.0	142.0	13.0
7	155.0	144.0	11.0
8	154.0	141.0	13.0
9	156.0	145.0	11.0
10	160.0	149.0	11.0
11	146.0	136.0	10.0
12	150.0	141.0	9.0
13	156.0	146.0	10.0
14	155.0	144.0	11.0
15	148.4	138.8	9.6
16	155.0	147.0	8.0
17	153.0	143.0	10.0
18	149.0	145.0	4.0
19	152.0	141.0	11.0
20	155.0	144.0	11.0
21	153.0	143.0	10.0
22	154.0	145.0	9.0
23	153.0	143.0	10.0
24	157.0	149.0	8.0
25	149.2	144.0	5.2
26	156.9	140.0	16.9
27	153.0	136.0	17.0

Results. The sample mean difference $(\overline{X} - \overline{Y})$ is 10.607 and the sample standard deviation (S) is 3.184. The resulting 90 percent confidence interval for the mean difference using Eq (2) is

$$= 10.607 \pm (1.645)(3.184/(27)^{1/2})$$

$$= 10.607 \pm 1.008$$

$$= (9.599,\ 11.615)$$

Since the confidence interval does not include zero, we reject the null hypothesis that the two models produce the same results.

Summary

Using the model building process described by Banks and Carson, a simulation model of the base level refueling process was designed to assess refueling capability. Data was collected from a tactical fighter wing which represented surge operations, and was used to identify model variables. The model was then built, verified and validated using an iterative process. The resulting model was run using two designs which reflected two decision alternatives. The model outputs were compared using a paired difference experiment and found to be statistically different thus demonstrating the model's usefulness as a decision making tool.

V. Conclusions and Recommendations for Further Research

Overview

This chapter provides a brief summary of the research effort. Then, conclusions of the research effort are presented. Finally, recommendations for further research are presented.

Research Summary

Recent changes in maintenance procedures and tactical aircraft have improved sortie generation capability. Fuels managers need a tool to aid in the effective utilization of refueling equipment and resources. The objective of this thesis was to design a simulation model to answer the question: What combination of available resources would provide fuels management with the most effective method of refueling under surge conditions.

In order to meet the stated objective, a simulation model was built using the reiterative model building process described in Chapter III. The first step was to define and formulate the problem. Next, the objective of the model building process was determined. The performance measure of completion time for the entire refueling operation was established for the model. In order to build the model, the base level refueling operation was analyzed as a system. The essence of the actual system was captured and used to build a simulation model. Data, collected from Langley AFB,

represented refueling operations under surge conditions. The data was used to determine values of variables in the model. The model was computerized using SLAM II simulation language.

Once computerized, the model was verified and validated. In order to determine if the output of the model could be used to aid the decision maker, a paired difference experiment was used to test the output of two different designs for the basic model. The models were run 27 times using common random number streams.

Conclusions

This research demonstrated the feasibility of developing a model for a microcomputer using SLAM II. Additional research efforts directed at validity of the refueling truck servicing aspect of the model are needed. Further research should be conducted to complete the validation of the model and additional modeling effort should be directed at other aspects of the Air Force fuels system. The conclusion of this research is that the base level refueling model represents a possible aid to decision making for fuels management at both the base and at higher headquarters as a capability assessment tool.

Further Research

Research Objective #1. The base fuels system can be represented as a network process. SLAM II's process orientation is ideally suited for simulating network

processes. All aspects of the Air Force's fuels system should be considered for modeling with SLAM II. Specifically for the base fuels system, SLAM II could provide a means to give an accurate assessment of the maximum and sustained dispensing capability for each base. Once the models are built, they would not change except for major construction efforts, redesign, or temporary system maintenance.

Research Objective #2. Refueling data should be collected for each major weapon system, aggregated, and used to determine appropriate distributions for refueling processes. The data could then be centrally maintained in a data base by MAJCOM. Any changes in capability submitted by a base could be verified using the model and input data.

Research Objective #3. An extensive verification and validation effort should be applied against the model to obtain a reliable representation of the base fuels system. If the model possesses a high degree of validity, the chances of its implementation by management are increased.

Research Objective #4. An improved version of the model with sufficient documentation should be incorporated into the training received at the fuels officer technical training course at Chanute AFB, Il. The model's experimentation process would give newly assigned fuels managers an introduction to refueling operations during surge conditions.

Appendix A: Glossary of Terms

Activity. Represents a time period of specified length required to complete some aspect of a process (1:6).

Attribute. The property of an entity. Attributes define the characteristics of the entity. Attributes may be changed during the simulation or may remain constant (1:6).

Bulk Storage. The storage facilities consisting of tanks for storing bulk petroleum products. Bulk storage tanks can be above or below ground and have capacities generally ranging from 1,000 barrels to 268,000 barrels (the U. S. petroleum industry uses 42 gallon per barrel as the standard barrel) (5:154; 207).

Classroom Support Computer (CSC). A Digital Equipment Corporation (DEC) VAX 11/785 computer running the Virtual Memory System (VMS) operating system.

Combat Quick Turn (CQT). Procedure for rearming and refueling an aircraft in a wartime aircraft surge operation. Once the aircraft lands and maintenance personnel determine the aircraft can be turned, the pilot is guided to a location where maintenance personnel, load crews, and refueling personnel are standing by to service the aircraft.

Cold Refueling. Conventional refueling of aircraft which do not have an engine operating. The term may be used to differentiate from hot refueling (4:72).

Continuous Simulation. Occurs when a dependent variable changes continuously over simulation time. For example, the amount of water behind a dam could be modeled with a continuous simulation (9:62).

Cryogenics. The science of refrigeration, with reference to methods for producing very low temperatures (4:72).

Discrete Simulation. This occurs when dependent variables change discretely at specific points in event time. For example, the number of aircraft waiting for a refueling truck (9:62).

Entity. Object with characteristics or attributes within the boundary of a discrete system. For example, aircraft and refueling trucks are entities in the refueling model (9:64).

Fuel Control Center (FCC). A centralized control point responsible for the operation of bulk storage, distribution, cryogenics production, and propellants functions (4:72).

Fillstand. A single point outlet used specifically for filling refueling trucks.

Hose Cart. Refueling equipment mounted on a cart and used to transfer fuel from a hydrant outlet to an aircraft. The cart filters and meters the fuel flow to the aircraft.

Hot Refueling. Single point pressure refueling of aircraft with at least one engine running (4:72).

Hydrant. The hydrant or hydrant outlet is the portion of a hydrant refueling system which can provide 600 to 1200 gpm (minus line and friction loss) through an outlet into an aircraft. A hose or other piece of equipment is used to connect the aircraft to the hydrant outlet (4:72).

Hydrant Refueling System. A series of pipelines, pumps, and outlets used to provide fuel to outlets on the aircraft parking ramp. Four basic designs are the Panero System, Pritchard System, Phillips System, and Type IV System.

JP4. Primary fuel for jet engine aircraft. A mixture of kerosene and highly volatile gasolines.

Network. A pictorial representation of a process (9:65).

Node. Used to model elements in a process such as queues, servers and decision points (9:65).

POL. A general term referring to all petroleum products (petrol, oils, and lubricants) handled by the FMO.

Process. A time-ordered sequence of events which may encompass several activities (9:65).

Refueling Trucks. Trucks with pumps, meters, and a large tank mounted on the chassis used to transfer fuel to and from aircraft or other equipment.

SLAM II. Simulation Language for Alternative Modeling, an advanced FORTRAN based language. The latest version of SLAM (9).

Appendix B: Data Collection and AID Program Output

Data was collected from the Daily Fuels Request and Servicing Log (AF Form 824) and the Flightline Daily Fuels Servicing Logs for 25 October and 5-7 November 1985. Figures 2 and 3 are examples of the forms used. The data extracted from the two forms were used to determine the values of variables in the model. Distributions were determined using the following methodology.

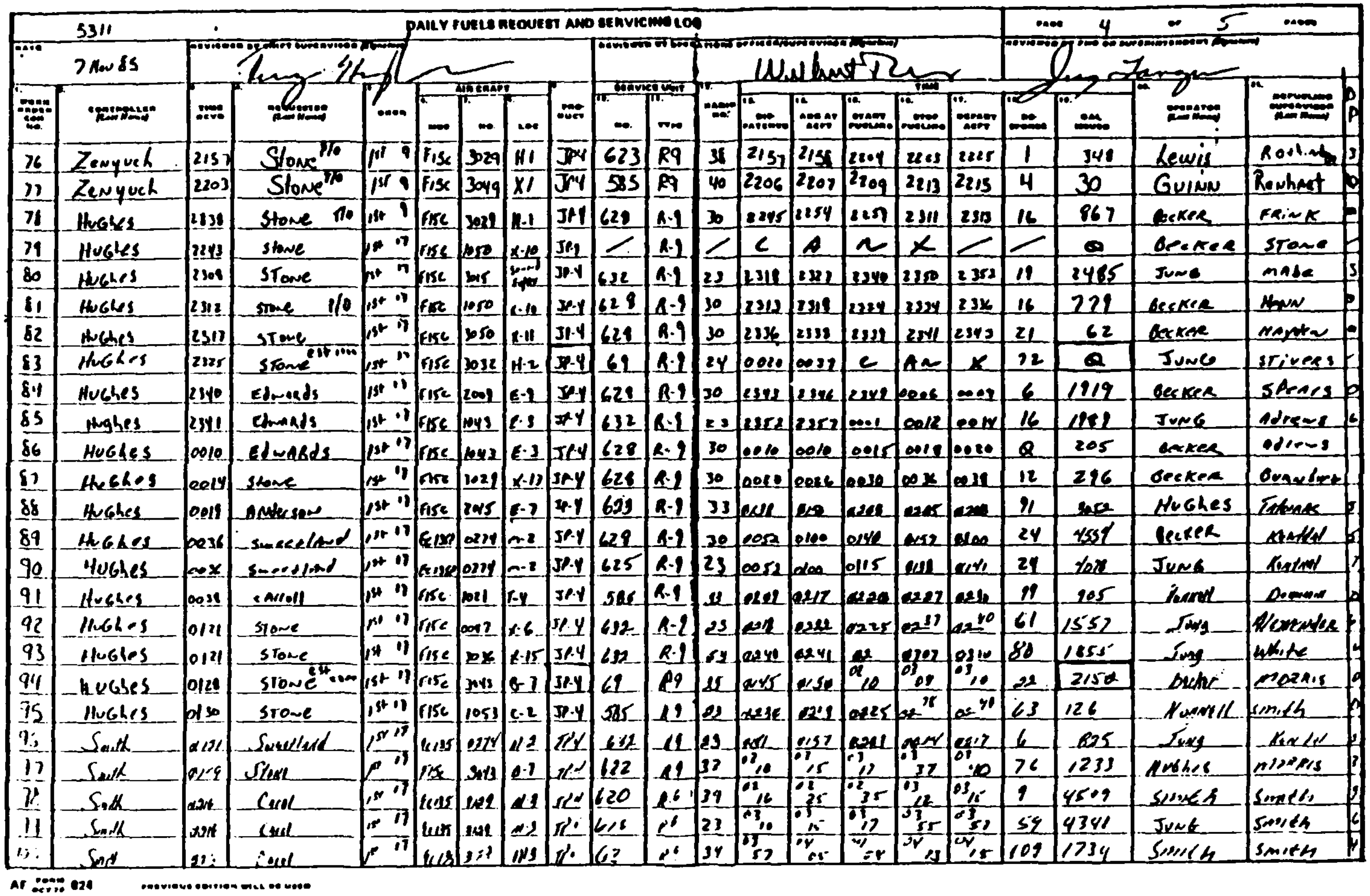
First, data was extracted from the appropriate row and column in the AF Forms 824 and 839 which represented the the time for the real world activity. Then, the data was used to build an input file for the AID program. AID ordered the data, transformed the data and built a histogram for the transformed data. Finally, the histogram was evaluated and a distribution was hypothesized. AID performed a Chi-square test for the distribution and displayed the critical values for accept/reject criteria. The following is the output from the AID program for each variable.

1. Hot Pit Servicing Distribution (Minutes).

Total Observations: 50

Input Data:

14	12	14	14	19	12	11	17	16	13
13	13	14	13	12	13	12	13	12	16
13	14	15	13	13	13	13	13	14	14
14	13	15	18	15	15	13	13	18	12
11	12	11	11	11	11	11	11	11	12



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DATE: 7 Nov 85

Work Order Con No.	Controller (Last Name)	Time Recvd	Requester (Last Name)	Orgn	Aircraft MDS	Aircraft No.	Aircraft Loc	Product	Service Unit No.	Service Unit Type	Radio No.	Dispatched	Arr at Acft	Start Fueling	Stop Fueling	Depart Acft	DD Forms	Gal Issued	Operator (Last Name)	Refueling Supervisor (Last Name)	D/P
76	Zenyuch	2157	Stone 7/0	1st 9	F15C	3029	H1	JP4	623	R9	38	2157	2158	2204	2203	2225	1	348	Lewis	Rothm[illegible]	3
77	Zenyuch	2203	Stone 7/0	1st 9	F15C	3049	X1	JP4	585	R9	40	2206	2207	2209	2213	2215	4	30	Guinn	Reinhart	D
78	Hughes	2238	Stone 1/0	1st 9	F15C	3029	H-1	JP4	629	R-9	30	2245	2254	2257	2311	2313	16	867	Becker	Frink	
79	Hughes	2243	Stone	1st 17	F15C	1050	X-10	JP4	/	R-9	/	C	A	N	X	/	/	@	Becker	Stone	
80	Hughes	2309	Stone	1st 17	F15C	3015	Spare Sqdn	JP-4	632	R-9	23	2318	2327	2340	2350	2352	19	2485	Jung	Mabe	S
81	Hughes	2312	Stone 1/0	1st 17	F15C	1050	C-10	JP-4	629	R-9	30	2313	2319	2324	2334	2336	16	779	Becker	Mann	
82	Hughes	2317	Stone	1st 17	F15C	3050	K-11	JP-4	629	R-9	30	2336	2338	2339	2341	2343	21	62	Becker	Mayton	
83	Hughes	2325	Stone est [illegible]	1st 17	F15C	3032	H-2	JP-4	69	R-9	24	0020	0037	C	AN	X	72	@	Jung	Stivers	
84	Hughes	2340	Edwards	1st 17	F15C	2009	E-9	JP-4	629	R-9	30	2343	2346	2349	0006	0009	6	1919	Becker	Spears	
85	Hughes	2341	Edwards	1st 17	F15C	1043	E-3	JP-4	632	R-9	23	2352	2357	0001	0012	0014	16	1989	Jung	Adrews	6
86	Hughes	0010	Edwards	1st 17	F15C	1043	E-3	JP-4	628	R-9	30	0010	0010	0015	0019	0020	Q	205	Becker	Adams	
87	Hughes	0014	Stone	1st 17	F15C	1029	X-17	JP-4	628	R-9	30	0020	0026	0030	0036	0039	12	296	Becker	[illegible]	
88	Hughes	0019	Anderson	1st 17	F15C	2015	E-7	JP-4	623	R-9	33	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	91	[illegible]	Hughes	[illegible]	
89	Hughes	0036	Sweetland	1st 17	F15C	0274	M-2	JP-4	629	R-9	30	0052	0100	0140	0157	0200	24	4554	Becker	Kendall	
90	Hughes	00X	Sweetland	1st 17	F15C	0274	M-2	JP-4	625	R-9	23	0052	0100	0115	0138	0141	24	4078	Jung	Kendall	7
91	Hughes	0038	Carroll	1st 17	F15C	1021	T-4	JP-4	586	R-9	33	0209	0217	0220	0227	0230	19	905	[illegible]	[illegible]	
92	Hughes	0121	Stone	1st 17	F15C	0097	X-6	JP-4	632	R-9	23	[illegible]	0222	0225	0237	0240	61	1557	Jung	Alexander	
93	Hughes	0121	Stone	1st 17	F15C	[illegible]	K-15	JP-4	632	R-9	53	0240	0241	[illegible]	0307	0310	80	1855	Jung	White	
94	Hughes	0128	Stone	1st 17	F15C	3043	G-7	JP-4	69	R9	35	0245	0250	02 10	03 09	03 10	22	2150	Becker	Morris	
95	Hughes	0130	Stone	1st 17	F15C	1053	C-2	JP-4	585	R9	03	[illegible]	[illegible]	0225	[illegible]	[illegible]	63	126	[illegible]	Smith	
96	Smith	0131	Sweetland	1st 17	F15C	0274	M-2	JP-4	632	R9	23	[illegible]	0157	[illegible]	[illegible]	[illegible]	6	835	Jung	[illegible]	
97	Smith	0159	Stone	1st 17	F15C	3043	G-7	JP-4	122	R9	37	03 10	03 15	03 17	03 37	03 40	76	1233	Hughes	Morris	
98	Smith	[illegible]	Carol	1st 17	F15C	[illegible]	M-3	JP-4	620	R-6	39	02 16	02 25	02 35	03 12	03 15	9	4509	[illegible]	Smith	
99	Smith	[illegible]	Carol	1st 17	F15C	[illegible]	M-3	JP-4	616	R-6	23	03 10	03 15	03 17	03 55	03 57	59	4341	Jung	Smith	
[illegible]	Smith	[illegible]	Carol	1st 17	F15C	[illegible]	M-3	JP-4	62	R-6	34	03 57	04 05	[illegible]	04 13	04 15	109	1734	Smith	Smith	

AF FORM 824 PREVIOUS EDITION WILL BE USED

Figure 2. AF Form 824, Daily Fuels Request and Servicing Log.

FLIGHTLINE DAILY FUELS SERVICE LOG															PAGE 3 OF 3 PAGES
DATE 5311		REVIEWED BY SHIFT SUPERVISOR (Signature) [illegible]								REVIEWED BY OPERATIONS SUPERVISOR (Signature) [illegible]					
WORK ORDER CON NO	AIRCRAFT ORGANIZATION	AIRCRAFT				SERVICE UNIT		TIME					GALLONS	OPERATOR	REFUELING SUPERVISOR
		MDS	TAIL NO	LOCATION	Product	NO.	TYPE	DISPATCHED	ARR ACFT	START FUEL	STOP FUEL	DEP ACFT			
				Pt	JP4	R/K	R/6								
37	1TFW	F15C	1054	3	R1	57	55	1820	1821	1822	1832	1833	2583	Taylor	Smith
38	1TFW	F15C	7037	3	R1	57	55	1858	1859	1900	1910	1911	2309	Taylor	Smith
39	1TFW	F15C	5550	3	R1	57	55	1918	1919	1920	1930	1931	1858	Taylor	Smith
40	1TFW	F15C	7043	3	R1	57	55	1932	1933	1934	1944	1945	1456	Taylor	Smith
41	1TFW	F15C	1037	3	R1	57	55	1946	1947	1948	1958	1959	1799	Taylor	Smith
42	1TFW	F15C	3036	3	R1	57	55	2000	2001	2002	2012	2013	1983	Taylor	Smith
43	1TFW	F15C	1054	3	R1	57	55	2014	2015	2016	2026	2027	2606	Taylor	Smith
44	1TFW	F15C	1026	3	R1	57	55	2026	2029	2030	2040	2041	1963	Taylor	Smith
45	1TFW	F15C	1052	3	R1	57	55	2114	2115	2116	2126	2127	1498	Taylor	Smith
46	1TFW	F15C	1025	3	R1	57	55	2128	2129	2130	2140	2141	1525	Taylor	Smith
47	1TFW	F15C	1054	3	R1	57	55	2142	2143	2144	2154	2155	2114	Taylor	Smith
48	1TFW	F15D	3049	3	R1	57	55	2156	2157	2158	2208	2209	1971	Taylor	Smith
49	1TFW	F15C	7052	3	R1	57	55	2213	2214	2215	2235	2236	2128	Taylor	Smith
													104,046		

AF FORM MAR 79 839

☆U.S. G.P.O. 1984-420 [illegible]

Figure 3. AF Form 839, Flightline Daily Fuels Service Log.

Ordered Data:

11	11	11	11	11	11	11	11	11	12
12	12	12	12	12	12	12	13	13	13
13	13	13	13	13	13	13	13	13	13
13	13	14	14	14	14	14	14	14	14
15	15	15	15	16	16	17	18	18	19

Histogram Statistics Discrete Data Set:

Cell No.	Obs. Freq.	Rel. Freq.	Cum. Freq.	Cell Value
1	0	0.000	0.000	0
2	0	0.000	0.000	1
3	0	0.000	0.000	2
4	0	0.000	0.000	3
5	0	0.000	0.000	4
6	0	0.000	0.000	5
7	0	0.000	0.000	6
8	0	0.000	0.000	7
9	0	0.000	0.000	8
10	0	0.000	0.000	9
11	0	0.000	0.000	10
12	9	0.180	0.180	11
13	8	0.160	0.340	12
14	15	0.300	0.640	13
15	8	0.160	0.800	14
16	4	0.080	0.880	15
17	2	0.040	0.920	16
18	1	0.020	0.940	17
19	2	0.040	0.980	18
20	1	0.020	1.000	19

Sample Statistics:

Mean	13.320
Standard Deviation	1.932
Minimum	11.000
Maximum	19.000

Transformed Data (Transformation: Addition of -10.000):

1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0	2.0
2.0	2.0	2.0	2.0	2.0	2.0	2.0	3.0	3.0	3.0
3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0
3.0	3.0	4.0	4.0	4.0	4.0	4.0	4.0	4.0	4.0
5.0	5.0	5.0	5.0	6.0	6.0	7.0	8.0	8.0	9.0

Histogram Statistics - Discrete Data Set:

Cell No.	Obs. Freq.	Rel. Freq.	Cum. Freq.	Cell Value
1	0	0.000	1.000	0
2	9	0.180	1.180	1
3	8	0.160	1.340	2
4	15	0.300	1.640	3
5	8	0.160	1.800	4
6	4	0.080	1.880	5
7	2	0.040	1.920	6
8	1	0.020	1.940	7
9	2	0.040	1.980	8
10	1	0.020	2.000	9

Sample Statistics:

Mean	3.320
Standard Deviation	1.932
Minimum	1.000
Maximum	9.000

Distribution Selected: Poisson

Initial Parameter Estimates:

Mean	3.320
Standard Deviation	1.822

Chi-Square Test

Hypothesis:

Distribution	Poisson
Mean	3.320
Standard Deviation	1.822

Test Parameters:

Degrees of Freedom	4
Level of Significance	0.100
Critical Value	7.779
Test Statistic	2.859

Results: Accept Hypothesis

Chi-Squared Test Computations:

Cell No.	Obs Freq.	Expected Freq.	Cell Statistic	Cell Value
1	9	7.81	0.182	0 1
2	8	9.96	0.387	2
3	15	11.02	1.433	3
4	8	9.15	0.145	4
5	4	6.08	0.709	5
6	6	5.86	0.003	6 7 8 9

2. <u>Truck Servicing Time Distributions (Minutes)</u>.

Total Observations: 50

Input Data:

21	26	25	20	19	18	17	22	25	20
13	13	18	23	22	21	17	17	20	17
14	18	18	21-	20	17	21	23	19	28
19	18	19	17	30	20	27	19	18	32
25	22	15	15	16	18	12	21	21	12

Ordered Data:

12	12	13	13	14	15	15	16	17	17
17	17	17	17	18	18	18	18	18	18
18	19	19	19	19	19	20	20	20	20
20	21	21	21	21	21	21	22	22	22
23	23	25	25	25	26	27	28	30	32
21	21	23	23	23	24	25	26	28	30

Histogram Statistics: Continuous Data Set

Cell No.	Obs. Freq.	Rel. Freq.	Cum. Freq.	Lower Bound	Upper Bound
1	7	0.140	0.140	12.000	15.333
2	14	0.280	0.420	15.333	18.667
3	19	0.380	0.800	18.667	22.000
4	5	0.100	0.900	22.000	25.333
5	3	0.060	0.960	25.333	28.667
6	2	0.040	1.000	28.667	32.000

Sample Statistics:

Mean	19.780
Standard Deviation	4.325
Minimum	12.000
Maximum	32.000

Transformed Data: (Transformation: Addition of -10.000)

2	2	3	3	4	5	5	6	7	7
7	7	7	7	8	8	8	8	8	8
8	9	9	9	9	9	10	10	10	10
10	11	11	11	11	11	11	12	12	12
13	13	15	15	15	16	17	18	20	22

Histogram Statistics: Continuous Data

Cell No.	Obs. Freq.	Rel. Freq.	Cum. Freq.	Lower Bound	Upper Bound
1	7	0.140	0.140	2.000	5.333
2	14	0.280	0.420	5.333	8.667
3	19	0.380	0.800	8.667	12.000
4	5	0.100	0.900	12.000	15.333
5	3	0.060	0.960	15.333	18.667
6	2	0.040	1.000	18.667	22.000

Sample Statistics:

Mean	9.780
Standard Deviation	4.325
Minimum	2.000
Maximum	22.000

Distribution Selected: Weibull

Initial Parameter Estimates:

Mean	9.780
Standard Deviation	4.325
Alpha	2.410
Beta	11.032

Chi-Square Test

Hypothesis:

Distribution	Weibull
Mean	9.780
Standard Deviation	4.325
Alpha	2.410
Beta	11.032

Test Parameters:

Degrees of Freedom	7
Level of Significance	0.100
Critical Value	12.017
Test Statistic	4.400

Results: Accept Hypothesis

Chi-Square Test Computations:

Cell No.	Obs Freq.	Expected Freq.	Cell Statistic	Lower Bound	Upper Bound
1	5	5	0.000	-INFINITY	4.336
2	2	5	1.800	4.336	5.920
3	7	5	0.800	5.920	7.192
4	7	5	0.800	7.192	8.348
5	5	5	0.000	8.348	9.475
6	5	5	0.000	9.475	10.638
7	6	5	0.200	10.638	11.915
8	5	5	0.000	11.915	13.440
9	3	5	0.800	13.440	15.594
10	5	5	0.000	15.594	+INFINITY

3. Travel Time to Fillstand Distribution

Total Observations: 75

Input Data (Ordered):

5	5	5	5	5	5	5	5	5	5
5	5	5	5	5	5	5	5	5	5
5	6	6	6	6	6	6	6	6	6
6	6	6	6	6	6	6	6	6	6
7	7	7	7	7	7	7	7	7	7
7	8	8	8	8	8	8	8	8	8
8	8	9	9	9	9	9	9	10	10
10	10	10	11	12					

Histogram Statistics: Discrete Data Set

Cell No.	Obs. Freq.	Rel. Freq.	Cum. Freq.	Cell Value
1	0	0.000	0.000	0
2	0	0.000	0.000	1
3	0	0.000	0.000	2
4	0	0.000	0.000	3
5	0	0.000	0.000	4
6	21	0.280	0.280	5
7	19	0.253	0.533	6
8	11	0.147	0.680	7
9	11	0.147	0.827	8
10	6	0.080	0.907	9
11	5	0.067	0.973	10
12	1	0.013	0.987	11
13	1	0.013	1.000	12

Sample Statistics:

Mean	6.813
Standard Deviation	1.730
Minimum	5.000
Maximum	12.000

Transformed Data (Transformation: Addition of -4.000)

1	1	1	1	1	1	1	1	1	1
1	1	1	1	1	1	1	1	1	1
1	2	2	2	2	2	2	2	2	2
2	2	2	2	2	2	2	2	2	2
3	3	3	3	3	3	3	3	3	3
3	4	4	4	4	4	4	4	4	4
4	4	5	5	5	5	5	5	6	6
6	6	6	7	8					

Histogram Statistics: Discrete Data Set

Cell No.	Obs. Freq.	Rel. Freq.	Cum. Freq.	Cell Value
1	0	0.000	1.000	0
2	21	0.280	1.280	1
3	19	0.253	1.533	2
4	11	0.147	1.680	3
5	11	0.147	1.827	4
6	6	0.080	1.907	5
7	5	0.067	1.973	6
8	1	0.013	1.987	7
9	1	0.013	2.000	8

Sample Statistics:

Mean	2.813
Standard Deviation	1.730
Minimum	1.000
Maximum	8.000

Distribution Selected: Poisson

Initial Parameter Estimates:

Mean	2.813
Standard Deviation	1.677

Chi-Square Test

Hypothesis:

Distribution	Poisson
Mean	2.813
Standard Deviation	1.677

Test Parameters:

Degrees of Freedom	3
Level of Significance	0.100
Critical Value	6.251
Test Statistic	3.159

Results: Accept Hypothesis

Chi-Square Test Computations:

Cell No.	Obs. Freq.	Expected Freq.	Cell Statistic	Cell Value
1	21	17.16	0.859	0 1
2	19	17.81	0.080	2
3	11	16.70	1.946	3
4	11	11.75	0.047	4
5	13	11.39	0.227	5 6 7 8

4. Fillstand Service Time Distribution (Minutes).

Total Observations: 75

Input Data (Ordered)

10	11	12	12	12	14	14	14	14	14
14	15	15	15	15	15	15	16	16	16
16	16	17	17	17	17	17	17	18	18
18	18	18	18	18	19	19	19	19	19
19	19	19	20	20	20	20	20	20	21
21	21	21	21	21	21	21	22	22	23
24	24	25	25	25	25	26	26	27	27
28	28	29	29	29					

Sample Statistics:

Mean	19.240
Standard Deviation	4.597
Minimum	10.000
Maximum	29.000

Histogram Statistics: Continuous Data Set:

Cell No.	Obs. Freq.	Rel. Freq.	Cum. Freq.	Lower Bound	Upper Bound
1	5	0.067	0.067	10.000	12.714
2	12	0.160	0.227	12.714	15.429
3	18	0.240	0.467	15.429	18.143
4	14	0.187	0.653	18.143	20.857
5	11	0.147	0.800	20.857	23.572
6	8	0.107	0.907	23.572	26.286
7	7	0.093	1.000	26.286	29.000

Distribution Selected: Normal

Initial Parameter Estimates:

Mean	19.240
Standard Deviation	4.597

Chi-Square Test

Hypothesis:

Distribution	Normal
Mean	19.240
Standard Deviation	4.597

Test Parameters:

Degrees of Freedom	12
Level of Significance	0.100
Critical Value	18.548
Test Statistic	18.00

Results: Accept Hypothesis

Chi-Square Test Computations:

Cell No.	Obs. Freq.	Expected Freq.	Cell Statistic	Lower Bound	Upper Bound
1	5	5	0.000	-INFIN	12.340
2	6	5	0.200	12.340	14.134
3	6	5	0.200	14.134	15.371
4	5	5	0.000	15.371	16.377
5	6	5	0.200	16.377	17.260
6	7	5	0.800	17.260	18.075
7	0	5	5.000	18.075	18.855
8	8	5	1.800	18.855	19.625
9	6	5	0.200	19.625	20.405
10	8	5	1.800	20.405	21.220
11	2	5	1.800	21.220	22.103
12	1	5	3.200	22.103	23.109
13	2	5	1.800	23.109	24.346
14	6	5	0.200	24.346	26.140
15	7	5	0.800	26.140	+INFIN

Appendix C: SLAM II Input Code, Operation, and Logic

This appendix lists the SLAM II input code and explains the operation and logic of the model. The purpose of this appendix is to provide a brief explanation of the operation of the code for those interested in expanding or modifying the model to meet their needs. For an indepth explanation of SLAM II code, consult Pritsker's text (9). The following model code was used for experimentation and analysis.

```
 1  GEN,LODEN,FUEL,7/22/86,2,YES,NO,YES,YES,YES,72;
 2  LIMITS,6,6,250;
 3  INTLC,XX(1)=10,XX(2)=4,XX(3)=0;
 4  NETWORK;
 5        CREATE,1,,2,200;
 6        GOON;
 7  SEL1  SELECT,SNQ,,,ACQ,ACP;
 8  ACQ   QUEUE(1),,2,BLOCK;
 9        ACT(4)/1,NPSSN(3.30,1)+XX(1),,FLY;
10  ACP   QUEUE(2),,2,BLOCK,RFL1;
11  TRK1  QUEUE(3),12,,,RFL1;
12  RFL1  SELECT,ASM,,,ACP,TRK1;
13  REF2  ACT(12)/2,WEIBL(11.032,2.41,2)+XX(1);
14        GOON,2;
15        ACT,,,FLY;
16  FSD   ACT,NPSSN(2.813,3)+XX(2),,FSD1;
17  FLY   COLCT,INT(2),TIME IN SYS,10,1,50;
18        ASSIGN,XX(3)=XX(3)+1;
19        TERM,48;
20  FSD1  GOON,1;
21        QUEUE(4);
22        ACT(3)/4,RNORM(19.2,4.6,4);
23        GOON;
24        ACT,NPSSN(2.813,5)+XX(2),,TRK1;
25        ENDNETWORK;
26  SEEDS,269376(1),5824(2),65872(3),12656(4),31215(5);
27  SIMULATE;
28  FIN;
```

Lines one through four are simulation control statements required for proper operation of the model. For

an indepth explanation, consult Pritsker's "Introduction to Simulation and SLAM II." (9:150).

Line five creates one aircraft entity every minute until 200 entities have been created. Additionally, attribute #2 is given the value of the time of creation for the entity. For example, if the entity is created at TIME = 50, attribute #2 is assign the value 50 (ATRIB(2)=50). SLAM II will automatically collect statistics for the attributes assigned to the entities and provide a summary of the statistics when the program is run.

Lines six and seven represent the aircraft approaching the aircraft servicing area. Line seven is a SELECT node labeled SEL1. The SELECT node routes the aircraft to either hot pit servicing (ACQ) or refueling truck servicing (ACP). It causes aircraft to chose the queue with the shortest waiting line. If both the hot pit queue and the refueling truck servicing queue have equal numbers waiting them, the hot pit queue is selected first.

Lines eight and nine represent the hot pit queue. When two aircraft are waiting for a service activity (one of the three hot pits) to become free, arriving aircraft are blocked and no more aircraft may enter the waiting line. Line nine represents the hot pits and assigns a servicing time for each aircraft based on a poisson distribution with a mean of 3.30 with an additional 10 minutes based on the data transformation. Once the aircraft have been serviced,

they are routed to the node labeled FLY where statistics on the entities are collected.

Lines 10-16 represent the refueling truck servicing process. Aircraft arrive at the aircraft parking area and wait for truck servicing. Line 10 sets a limit of two on the number of aircraft that can wait for refueling trucks. All other entities are blocked and either routed to the hot pit or the entity is destroyed. Line 11 is the queue for refueling trucks awaiting the arrival of aircraft. Initially, there are 12 refueling truck entities waiting in the queue. No additional refueling trucks will be created in the program. Line 12 sets a requirement for an entity to be in each queue before they can proceed with servicing. The aircraft and refueling truck entities are actually joined together for the service activity (line 13). The attributes of the aircraft entity are saved by the newly created entity. Line 13 services the entity for a time period based on a Weibull distribution.

The combined entity is serviced for the randomly generated time period and then proceeds to line 14. Line 14 splits the entity into two entities, one aircraft entity and one truck entity. The aircraft entity goes to line 15 and is sent to the node labeled FLY for collection of statistics. The truck entity goes to the activity node labeled FSD (line 16). It is then sent to the fillstand servicing module which starts with the node labeled FSD1

(line 20). The refueling truck must refill after every aircraft servicing.

Lines 17-19 collect statistics on the aircraft entities and cause the simulation to terminate when 48 aircraft have been serviced (line 19). Line 18 is a counter used to keep track of the number of aircraft refueled during the trace function.

Lines 20-24 represent the fillstand operation for refueling trucks. Refueling trucks arrive at the node labeled FSD1 (line 20) and queue (line 21) for fillstand servicing (line 22). The time required to service the refueling truck is normally distributed. Once serviced, the refueling truck travels to the aircraft parking area. This activity is represented by line 24. A travel time is assign according to a poisson distribution. The truck arrives at the node labeled TRK1 (line 11) and is now ready to service the next aircraft waiting in the queue with the node labeled ACP (line 10).

Lines 25-28 are simulation control statements. Line 25 used to signal the end of the network. Line 26 sets the initial random number generator seed for the first simulation run. Line 27 is used when multiple runs are required. Additionally, when multiple runs are required, more SEED statements (line 26) may be added when control of the random number generator seed is required. Line 28 is the last statement signifying the end of all program inputs.

Figure 4 is a flow diagram of the program used to illustrate the logical paths the entities take in the operation of the model. Table V lists the area numbers from Figure 4 and gives the corresponding line numbers from the model code.

TABLE V

Comparison of Diagram to Model Code

Area number	Model Code
1	Line 5
2	Lines 6-10
3	Lines 17-19
4	Lines 12-13
5	Lines 14-15
6	Lines 20-24 and Line 11

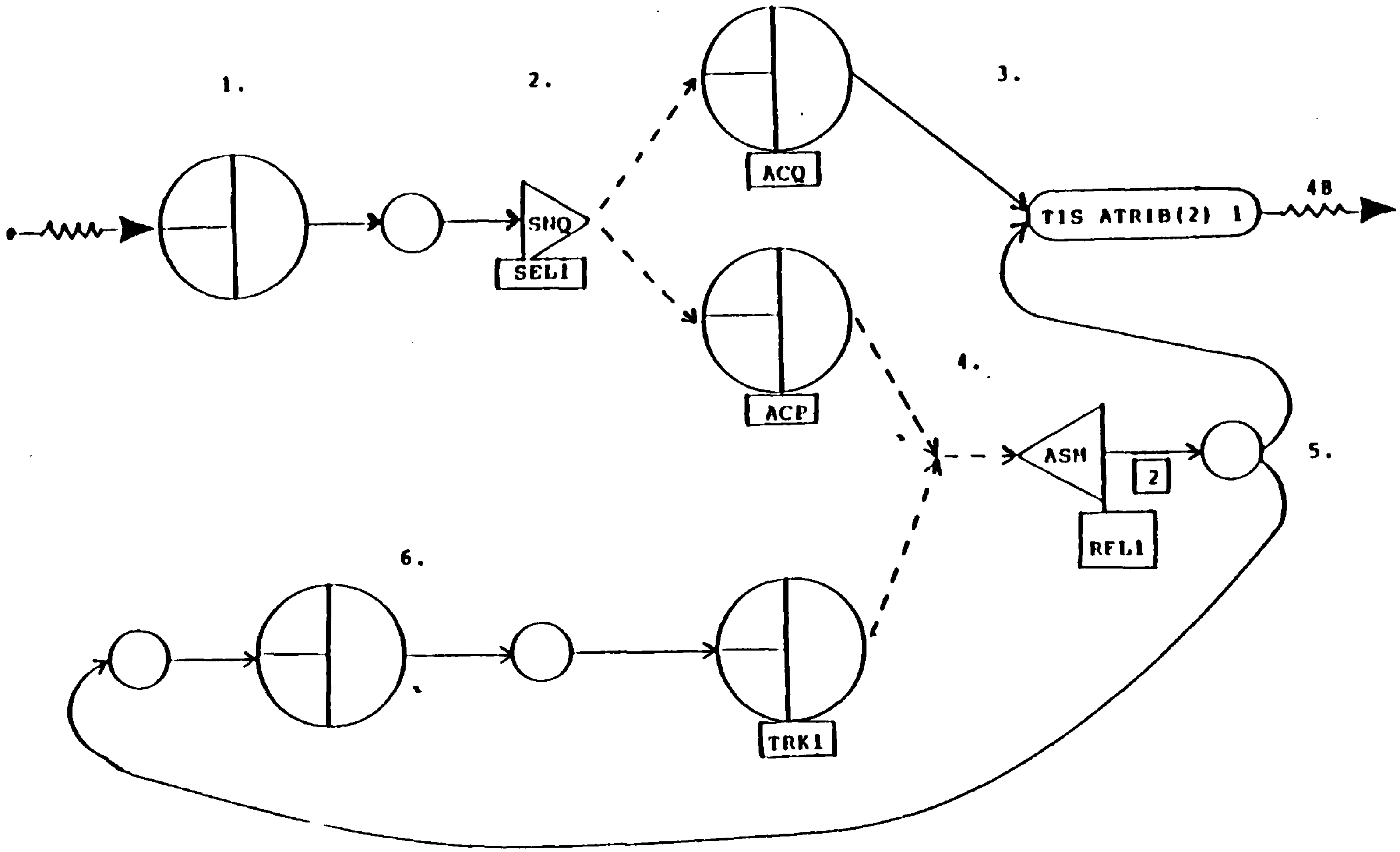

Figure 4. Flow Diagram Using SLAM II Pictorial Representation

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VITA

Captain Gary A. Loden was born 28 July 1952 in Flint Michigan. He graduated from Haleyville High School, Haleyville, Alabama, in 1970. He received a degree of Bachelor of Arts in Business/Economics 1975 from Park College, Kansas City, Missouri. He received his commission in the USAF through OTS in 1978.

Captain Loden's first assignment was as a Supply Staff Officer with the 4756th Supply Squadron, Tyndall AFB, Fl. He was reassigned to the Air Defense Weapons Center, Tyndall AFB, Fl, as Materiel Support Officer. In February 1980, he was reassigned to the 400th Munitions Maintenance Squadron, Kadena AB, Japan, as Munitions Accountable Supply Officer until May 1983. While assigned to Kadena AB, he received a degree of Masters of Science in Systems Management from the University of Southern California in May 1982. In June 1983, he was reassigned to the 366th Supply Squadron as the Fuels Management Officer, Mountain Home AFB, Id. He entered the School of Systems and Logistics, Air Force Institute of Technology, in May 1985.

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This research develops a simulation model to of the base level refueling operation during surge conditions. Refueling data, representing surge operations, was collected and used to describe model variables. A simulation language available on the Z-100 microcomputer, SLAM II, was used to encode the model. The model simulated the refueling of aircraft under surge operations using refueling trucks, hot pits, and fillstands. The model is general enough to allow the user to vary the number of aircraft, refueling trucks, hot pits, and fillstands in order to determine how long the refueling operation will take.

The analysis was accomplished using a paired difference experiment. Two individual designs, having different combinations of refueling equipment, were tested to determine if the model could provide the decision maker with the best configuration of equipment. The results of the experiment indicated that the model could provide an output useful in choosing between alternative configurations of equipment.

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